Medical Geology and Research on Environmental Health
(Effects of Metals)

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“In its broadest sense, environmental health comprises those aspects of human health, disease and injury that are determined or influenced by factors in the environment.

This includes not only the study of the direct pathological effects of various chemical, physical and biological agents, but also the effects on health of the broad physical and social environment, which includes housing, urban development, land-use and transportation, industry and agriculture”.

-Healthy People 2010
Environmental Health
An Approach to the Study of Human Diseases

Environmental Exposure

Intrinsic Susceptibility (Physiology & Genetics)

Health and Disease

Age / Time
Environmental Exposure and Risk of Disease

Traditional Approach

EXPOSURE

INTERNAL DOSE

TARGET TISSUE DOSE

DISEASE

ALTED STRUCTURE FUNCTION

EARLY BIOLOGICAL EFFECTS
Metals (and metalloids) affect many targets

- Lead: brain, blood formation
- Mercury: brain, heart function
- Nickel and chromate: allergy, cancer
- Cadmium: kidneys
- Arsenic: skin, bladder, liver, kidneys
- Several metals: cancer risk
Risk Assessment Issues Related To Metals

- Different valence states of metals and different metal compounds produce different health and/or carcinogenic response.
- Metals are part of the background.
- Animal and human responses are not consistent.
- Variation in individual susceptibility.
- Bioavailability vs Bioaccessibility of metals.
Different Valence States of Metals and Metal Compounds

- Not every valence state of the metals known to be carcinogenic in humans has been associated with an increased risk of cancer (e.g., Cr$^{3+}$, As$^0$, metallic nickel).

- Various theories exist about the carcinogenicity of different metal compounds (e.g., solubility).
Metals Are Part of the Background

- Human exposure to metals is only partly anthropogenic. Metals, including carcinogenic metals, are naturally found as part of the earth’s crust, in the air and water, and in food.

- Arsenic in drinking water occurs in numerous places in the world as a result of a geochemical phenomenon at exposures high enough to produce health effects including cancer.
Animal and Human Responses are not Consistent

- Few animal studies report a carcinogenic response by inhalation or ingestion of the metals known to be carcinogenic in humans (e.g., arsenic shows little if any carcinogenic response by any route in animals; chromium and nickel demonstrate strong responses by bronchial implantation in animals, but little by inhalation or ingestion).

- Assessment of the carcinogenic risk of metals for humans is based on human data, including dose-response assessment.
There is Evidence of Variation in Individual Susceptibility to Certain Metals (Arsenic as an Example)

- Whites may be more susceptible to arsenic induced skin cancer.
- Smokers may be at greater risk or arsenic-induced or chromium-induced lung cancer.
- Diet appears to have an effect on arsenic-induced skin cancer (poorer diets have greater risk of disease)
- Risk assessment needs to consider those at greater risk as well as the risk of the general population.
The Importance of Bioavailability

- “The rate and extent to which a substance is absorbed and becomes available at the site of drug action”.

- Ex. Bioavailability of “lead”
  - **Adults** absorb about 5-15% of ingested lead, usually retaining less than 5% of absorbed lead
  - **Children** absorb about 41.5% of ingested lead, which is related age and development of GI tract.
Bioavailability (cont.)

• Nutritional and dietary factors influence “lead” toxicity
  – Low dietary iron and calcium enhance lead absorption.

• Vitamin C reduces “lead” absorption
  – Increases iron absorption, decreasing the ability of lead to compete for binding
What is bioaccessibility?

Bioaccessibility - the fraction that is soluble in the gastrointestinal environment and is available for absorption.
The Importance of Bioaccessibility
Ex. Arsenic in Soils

- typically between 10 and 30% of arsenic in the soil is bioaccessible
- risk assessments assuming 100% bioaccessibility will overestimate exposure
- this could lead to overestimates of risk and remediation or limitations on development
(After Ruby et al., 1999)
To study trace elements, especially their bioaccessibility, bioavailability, geo-availability;

To establish baseline or background levels... natural occurrence and distribution.

To implement the use of geographic, biomedical, pathological, epidemiological and toxicology tools to obtain a better understanding on the distribution, mobility and levels of toxic trace elements.
Medical Geology and Human Health

General Research Priorities (cont.)

- Weather-related morbidity;

- Water- and vector-borne diseases;

- Assessment of natural and ambient sources of mercury and arsenic (i.e., health effects due to coal combustion, contaminated food, soil, and water)
Medical Geology

*Links to Human Diseases*

Natural and Mineral Dust

Water-Borne Diseases

Volcanic Emissions

Health Effects

Trace Elements/Toxic Metals

(I.e., DU, Ra, Pb, As, Hg)

Cancer

(prostate, breast)

Emerging Infectious Diseases
Considerations for Conducting Environmental Health Studies of Metals

- Sources of data (e.g., mortality data, incidence data, personnel records)
- Effect being studied (lung cancer, skin cancer, etc.)
- Designs for study (e.g., prospective, case-control, cross-sectional)
- Confounding (e.g., smoking and lung cancer, other carcinogens)
- Latency period from exposure till disease
- Exposure information
- Statistical power (considers background disease rate, size of population being studied, etc.)
- Species of metal (e.g., valence, compound, etc.)
Environmental exposures follow complex pathways.
You are what you eat

- *Hydroxylapatite*, Ca$_5$(PO$_4$)$_3$(OH), is the mineral in bone. Actually, many other cations can substitute for calcium within the crystal structure of hydroxylapatite.
- *Magnesium* is one possible substitute for calcium. That the bones can be a source of magnesium may become important when ingestion levels of the element are inadequate.
- *Strontium* is another calcium substitute.
- One of the most thoroughly researched ions that partition into apatite is *fluorine* high water concentrations were shown in the early decades of the 20th century to be responsible for mottled teeth. Typical symptoms of fluorosis include dental fluorosis, or mottling of tooth enamel, and various forms of skeletal fluorosis including, osteosclerosis, limited movement of the joints, and outward manifestations such as knock-knees, bowlegs and spinal curvature. Fluorosis combined with nutritional deficiencies in children can result in severe bone deformation.
- Human nutritional requirements include calcium, phosphorous, magnesium and fluorine if we wish to maintain a healthy, mineralized skeletal and dental system. All nutrients come from Earth's rocks and minerals, the bailiwick of geologists.
Nine Indoor Air Hazards
1-Moisture and biologicals (such as molds, mildew and dust mites).
2-Combustion products, including carbon monoxide.
3-Formaldehyde.
4-Radon.
5-Household products and furnishings.
6-Asbestos.
7-Particulates.
8-Remodeling byproducts.
9-Environmental tobacco smoke.
“High levels of arsenic in drinking water has caused severe health problems in many countries. In West Bengal alone, over 50 million people are at risk of developing arsenic poisoning” *Lancet*, 2002
Important to medical geology because:

Significantly more quantitative than estimation of risk and more directly controlled by environmental and geological factors, intervention possible!

Where You Live?  Soil You Eat?  Water You Drink?
Children's Environmental Health

- Deficiencies
  - Iodide, zinc

- Toxic effects
  - Lead, asbestosis, zinc

- Side effects
  - Directs effect
    - Dust, copper, ionized and non ionized-radiation
  - Indirect effect
    - Obesity
Environmental pollutants and disease in American Children: Estimates of morbidity, mortality and costs for lead poisoning, asthma, cancer and developmental disabilities.

- 100% lead poisoning, 30% asthma, 5% cancer, 10% neurobehavioral disorders

- 43.4 billion USD lead poisoning, 2 billion USD for asthma, 0.3 billion USD for childhood cancer, 9.2 billion USD for neurobehavioral disorders, total annual cost 54.9 billion USD
Medical Geology is defined as the science dealing with the relationship between geological materials and geologic processes and their impacts on health problems in man and animals.

The scope and range of Medical Geology include:

- identifying and characterizing natural sources of harmful materials in the environment;
- learning how to predict the movement and alteration of chemical, infectious, and other disease-causing agents;
- and understanding how people may be exposed to such materials.
Our Natural Environment and Health

Lake Nyos, Cameroon
Environmental Tragedy
Groundwater arsenic calamity in Bangladesh


School of Environmental Studies, Jadavpur University, Calcutta 700 032, India
*Dhaka Community Hospital, Malibagh, Dhaka 1219, Bangladesh
**National Institute for Preventive and Social Medicine, Mahakati, Dhaka 1212, Bangladesh


Bangladesh victim of world’s worst mass poisoning

Arsenic-tainted water blamed for sickness, death

By Paul Salopek
Chicago Tribune

NOVAPARA, Bangladesh — When the mysterious sores first appeared on Anil Chandra Das’ work-toughened hands, the grizzled rice farmer, long hardened against the aches and pains of life in rural Bangladesh, just ignored them. But the lesions didn’t go away. Instead, the small village near Nabadwip remained inert.

“My parents told me to leave home when I got sick. They said the spirits of our house were displeased,” said Nowladar.

Experts say the arsenic-beneath Bangladesh’s fertile river deltas was probably deposited long ago after washing down from bodies of water in the Himalayas. As long as the arsenic compounds — called pesticides — remained inert.

The cast of characters in the emerging health crisis includes armies of quack doctors who prey on the poisoned victims, knowing the disease has arrived.

But with the advent of intensive irrigation in the 1970s, the aquifers have dropped, exposing the poisons to oxygen for the first time.

Once oxidized, arsenic sulfides become water-soluble.

And like tea seeping from a bag, they percolate from subsols into drinking water tables with every monsoon flood.

So the leading theory goes.

“Nobody knows, exactly,” says Prasenjeet Sinha, a Bangladesh Medical Research Council scientist who has followed arsenic poisoning outbreaks in Taiwan, Chile, Mexico and the western United States.

Most of those incidents have sickened a few thousand people.

One reason the world’s worst arsenic epidemic has been so muted, Gibb said, is that — contrary to its sinister, suicide-capsule reputation — arsenic poisoning can be undramatic, even stealthy.

Even wells (dug with 200 times the World Health Organization’s safe maximum of 0.1 milligrams) have been found near Sona’s village, will not kill outright.

Instead, a buildup of the lethal chemical, over months or years causes a wide array of increasingly debilitating ailments, from lesions on the hands and feet to organ cancers, neural disorders, deafness and, possibly, even diabetes.

“Just wait, you’ll start seeing patterns of cancers pop up in this region in a few years,” said Gibb.

“This is a major tragedy exactly because it’s progressive and the pa...
Definitions

**Bioavailability** - the fraction of an administered dose that reaches the central (blood) compartment from the gastrointestinal tract.

**Bioaccessibility** - the fraction that is soluble in the gastrointestinal environment and is available for absorption.